
Comanche Station, Pueblo, Colorado

Groundwater Monitoring System Certification

for Compliance with the Coal Combustion Residuals (CCR) Rule

Comanche Station

Xcel Energy

August 1, 2016
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Table of Abbreviations and Acronyms

Abbreviation	Definition
ADF	Ash Disposal Facility
CCR	Coal Combustion Residuals
EPA	U.S. Environmental Protection Agency
TSS	Total Suspended Solids

Certification

Groundwater Monitoring System for Compliance with the Coal Combustion Residuals Rule

Public Service Company of Colorado, an Xcel Energy Company

Comanche Station, Pueblo County, Colorado

I hereby certify that the groundwater monitoring system at Comanche Station is designed to meet the performance standard in Sections 257.91(a)(1) and (2) of the Federal Coal Combustion Residuals Rule, and that the groundwater monitoring system has been designed and constructed to ensure that the groundwater monitoring will meet this performance standard for the CCR units located at Comanche Station.

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1.0 Introduction

The U.S. Environmental Protection Agency's (EPA's) final Coal Combustion Residuals (CCR) Rule establishes a comprehensive set of requirements for the management and disposal of CCR (or coal ash) in landfills and surface impoundments by electric utilities. Comanche Station, located in Pueblo, Colorado (**Figure 1**), is owned and operated by Public Service Company of Colorado (PSCo), an Xcel Energy Company. Comanche Station has two CCR units subject to the CCR Rule: an impoundment (Bottom Ash Pond) and a landfill (Ash Disposal Facility; ADF) (**Figure 2**).

This document supports compliance with the CCR Rule by demonstrating that the groundwater monitoring system at Comanche Station meets the requirements outlined in Section § 257.91 of the Rule, which states:

- *Section § 257.91(f): 'The owner or operation must obtain a certification from a qualified professional engineer stating that the groundwater monitoring system has been designed and constructed to meet requirements of this section [§257.91]. If the groundwater monitoring system includes the minimum number of monitoring wells specified in paragraph (c)(1) of this section [Section § 257.91], the certification must document the basis supporting this determination.'*

Table 1 summarizes components required by groundwater monitoring systems, per the CCR Rule and the professional engineer's certification of compliance with these requirements. The remainder of this document provides information to support certification for the groundwater monitoring system for the two CCR units at Comanche Station.

Table 1. Summary of 40 CFR Section § 257.91 Groundwater Monitoring System Requirements and Site-Specific Compliance	
Groundwater Monitoring System Requirements	**Compliance with Requirement**
(a) *Performance standard.* The owner or operator of a CCR unit must install a groundwater monitoring system that consists of a sufficient number of wells, installed at appropriate locations and depths, to yield groundwater samples from the uppermost aquifer that: (1) Accurately represent the quality of background groundwater that has not been affected by leakage from a CCR unit. A determination of background quality may include sampling of wells that are not hydraulically upgradient of the CCR management area where: (i) Hydrogeologic conditions do not allow the owner or operator of the CCR unit to determine what wells are hydraulically upgradient; or (ii) Sampling at other wells will provide an indication of background groundwater quality that is as representative or more representative than that provided by the upgradient wells; and (2) Accurately represent the quality of groundwater passing the waste boundary of the CCR unit. The downgradient monitoring system must be installed at the waste boundary that ensures detection of groundwater contamination in the uppermost aquifer. All potential contaminant pathways must be monitored.	**Yes.** A groundwater monitoring system has been established that includes the minimum number of wells at appropriate locations and depths to yield uppermost groundwater samples surrounding each CCR facility. See Sections 3 and 4.
(b) The number, spacing, and depths of monitoring systems shall be determined based upon site-specific technical information that must include thorough characterization of: (1) Aquifer thickness, groundwater flow rate, groundwater flow direction including seasonal and temporal fluctuations in groundwater flow; and (2) Saturated and unsaturated geologic units and fill materials overlying the uppermost aquifer, materials comprising the uppermost aquifer, and materials comprising the confining unit defining the lower boundary of the uppermost aquifer, including, but not limited to, thicknesses, stratigraphy, lithology, hydraulic conductivities, porosities and effective porosities.	**Yes.** The monitoring system was designed based on results of technical, site-specific data, including (b)(1) and (b)(2). See Sections 3 and 4.
(c) The groundwater monitoring system must include the minimum number of monitoring wells necessary to meet the performance standards specified in paragraph (a) of this section, based on the site-specific information specified in paragraph (b) of this section. The groundwater monitoring system must contain: (1) A minimum of one upgradient and three downgradient monitoring wells; and (2) Additional monitoring wells as necessary to accurately represent the quality of background groundwater that has not been affected by leakage from the CCR unit and the quality of groundwater passing the waste boundary of the CCR unit.	**Yes.** Monitoring wells that meet the performance standards are located at each CCR unit (six wells surrounding the impoundment and nine wells surrounding the landfill) in compliance with the CCR Rule. See Section 4.

Table 1. Summary of 40 CFR Section § 257.91 Groundwater Monitoring System Requirements and Site-Specific Compliance	
Groundwater Monitoring System Requirements	**Compliance with Requirement**
(d) The owner or operator of multiple CCR units may install a multiunit groundwater monitoring system instead of separate groundwater monitoring systems for each CCR unit. (1) The multiunit groundwater monitoring system must be equally as capable of detecting monitored constituents at the waste boundary of the CCR unit as the individual groundwater monitoring system specified in paragraphs (a) through (c) of this section for each CCR unit based on the following factors:(i) Number, spacing, and orientation of each CCR unit; (ii) Hydrogeologic setting; (iii) Site history; and (iv) Engineering design of the CCR unit. (2) If the owner or operator elects to install a multiunit groundwater monitoring system, and if the multiunit system includes at least one existing unlined CCR surface impoundment as determined by §257.71(a), and if at any time after October 19, 2015 the owner or operator determines in any sampling event that the concentrations of one or more constituents listed in appendix IV to this part are detected at statistically significant levels above the groundwater protection standard established under §257.95(h) for the multiunit system, then all unlined CCR surface impoundments comprising the multiunit groundwater monitoring system are subject to the closure requirements under §257.101(a) to retrofit or close.	There is no multiunit monitoring system at Comanche. See Sections 2 and 4.
(e) Monitoring wells must be cased in a manner that maintains the integrity of the monitoring well borehole. This casing must be screened or perforated and packed with gravel or sand, where necessary, to enable collection of groundwater samples. The annular space (*i.e.,* the space between the borehole and well casing) above the sampling depth must be sealed to prevent contamination of samples and the groundwater. (1) The owner or operator of the CCR unit must document and include in the operating record the design, installation, development, and decommissioning of any monitoring wells, piezometers and other measurement, sampling, and analytical devices. The qualified professional engineer must be given access to this documentation when completing the groundwater monitoring system certification required under paragraph (f) of this section. (2) The monitoring wells, piezometers, and other measurement, sampling, and analytical devices must be operated and maintained so that they perform to the design specifications throughout the life of the monitoring program.	**Yes.** Well design meets requirements (e). See Section 4. Groundwater monitoring system will be operated and maintained per (e)(2).
(f) The owner or operator must obtain a certification from a qualified professional engineer stating that the groundwater monitoring system has been designed and constructed to meet the requirements of this section. If the groundwater monitoring system includes the minimum number of monitoring wells specified in paragraph (c)(1) of this section, the certification must document the basis supporting this determination.	**Yes.** System designed and constructed to meet the requirements of Section §257.91. Technical information to support certification and number of wells, per (c)(1). See Sections 2.0, 3.0 and 4.0.

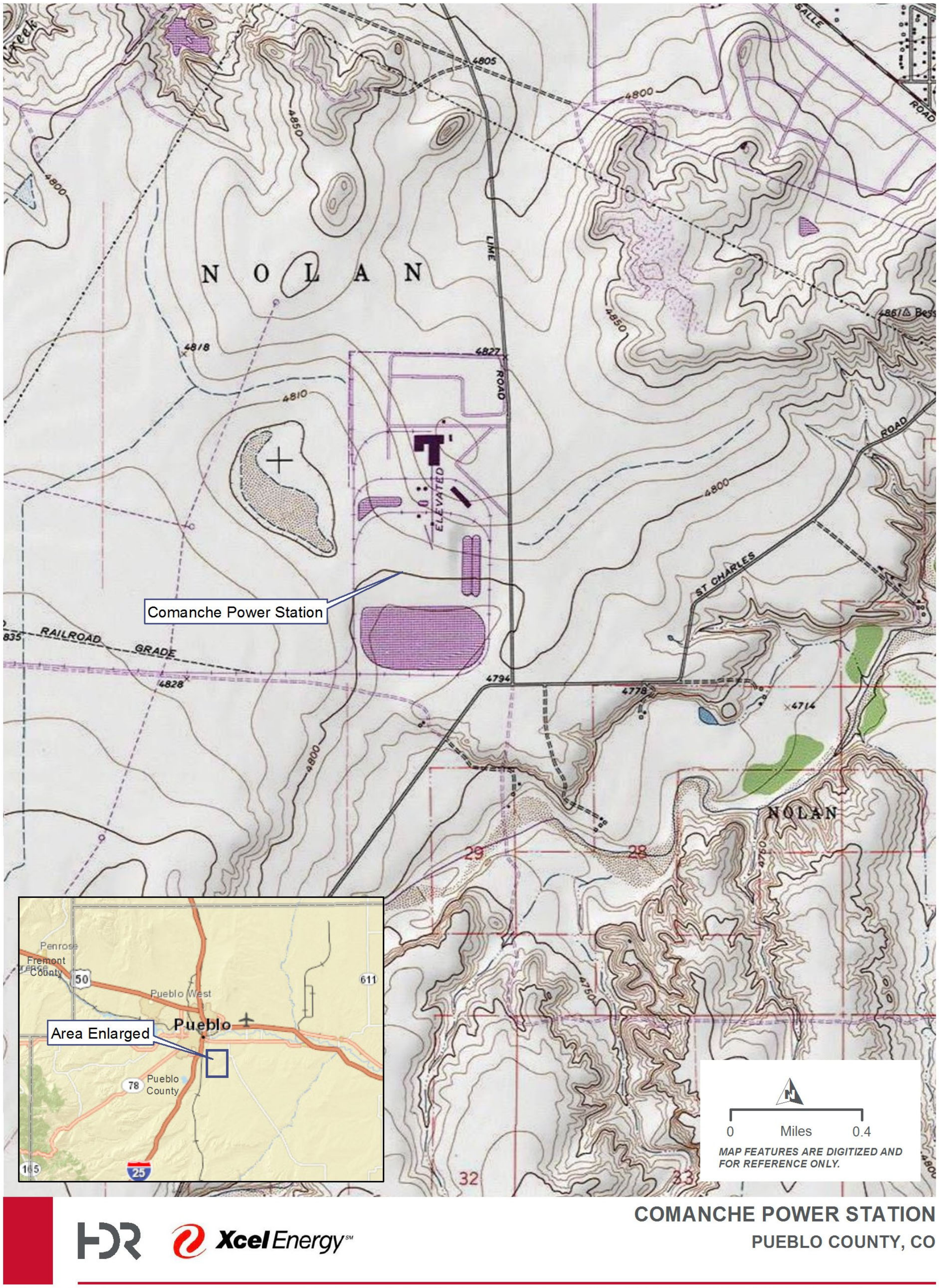

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Figure 1. Vicinity Map for Comanche Station

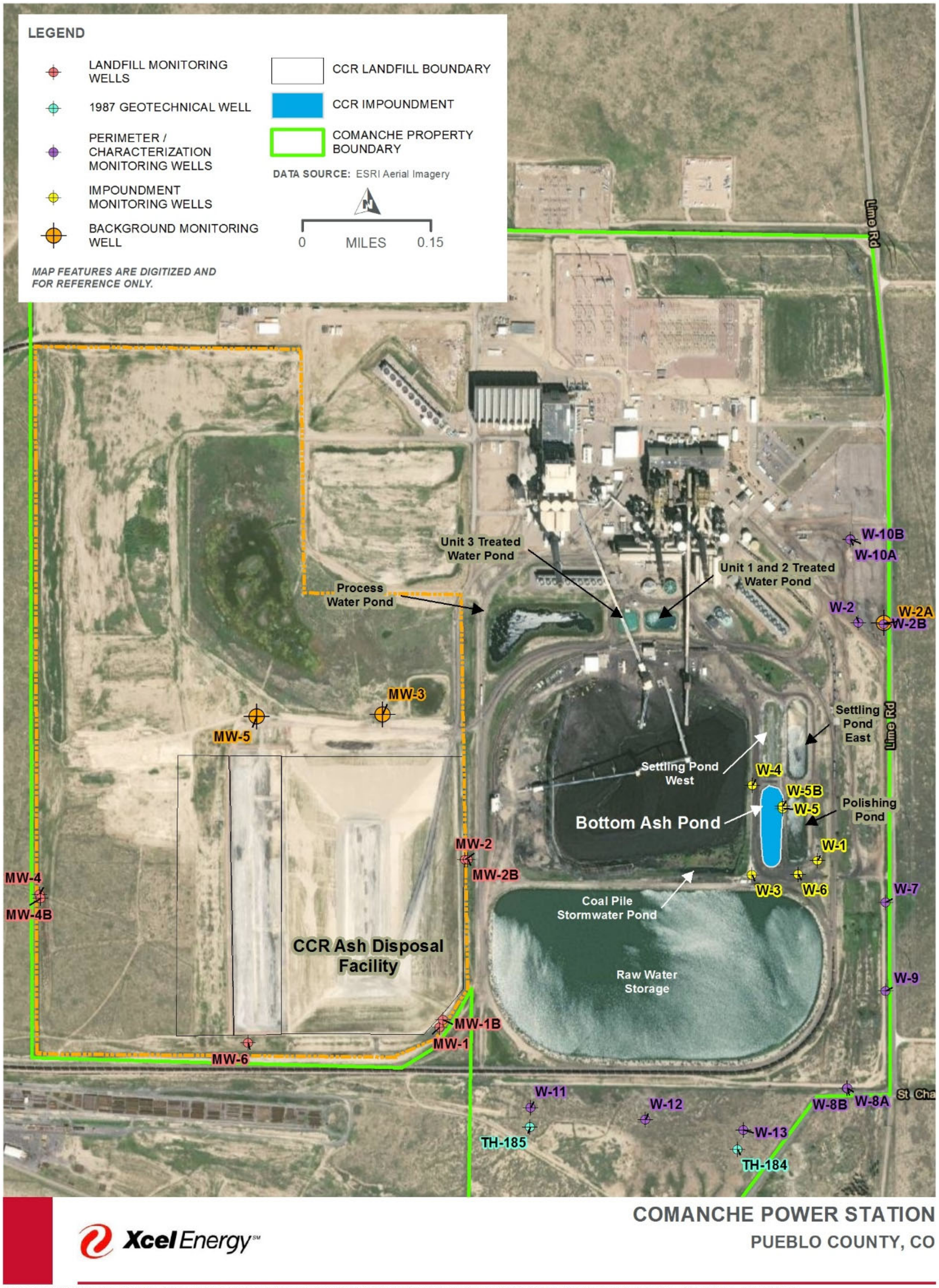

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Figure 2. Comanche Station – CCR Units and Monitoring Well Location Map

2.0 Facility Description

Comanche Station is a coal-fired plant consisting of three units (Units 1, 2, 3) that burn Powder River Basin coal. Unit 1 was built in 1973, Unit 2 was built in 1975, and Unit 3 was built in 2010 (Tetra Tech, 2012). Comanche Station currently has two CCR units subject to the CCR Rule: a landfill and an impoundment (**Figure 2**). The sections that follow provide a brief description of the CCR units.

Additional ponds at the facility include process water, settling, polishing, and raw water storage ponds. These units do not hold CCR, and therefore are not considered CCR units, in compliance with the CCR Rule:

> *"CCR surface impoundments do not include units generally referred to as cooling water ponds, process water ponds, wastewater treatment ponds, storm water holding ponds, or aeration ponds. These units are not designed to hold an accumulation of CCR, and in fact, do not generally contain significant amounts of CCR."*

2.1 CCR Landfill

The CCR landfill, also known as the CCR Ash Disposal Facility (**Figure 2**), is an approximately 280-acre engineered ash monofill consisting of eight permitted disposal cells. Currently, disposal is occurring in two cells in the southeast corner of the permitted landfill. Cell 1 was constructed with a clay liner (Xcel Energy, 2005), and Cell 2E was constructed with CCR Rule compliant liner and leachate collection systems. The additional disposal cells will be constructed in phases as needed to contain ash and waste from power generating activities. Fly ash from all three units is collected in silos for disposal in the landfill. Bottom ash is also permitted to be disposed in the on-site landfill, if needed. Water treatment sludge (lime from an on-site treatment system), process water pond sediment, coal impurities, and excavation soils are also permitted for disposal at the landfill (Tetra Tech, 2015).

2.2 CCR Impoundment

Bottom ash generated from Units 1 and 2 was sluiced to the Bottom Ash Pond for dewatering and temporary storage until June 2021. Bottom ash solids were routinely excavated from the impoundment and either beneficially used off-site or transported to the landfill for disposal. Bottom ash is removed from Unit 3 dry via a submerged flight conveyor (SFC) and does not go into the Bottom Ash Pond; it is transported dry either to off-site beneficial use or to the landfill for disposal. According to historic documents, the impoundment was constructed in 1972 with a three-foot thick clay liner; however, this liner does not meet the requirements of the CCR Rule. The impoundment is 513 feet long by 138 feet wide and 26 feet deep with a surface area of 1.6 acres. The primary influent to the CCR impoundment is sluiced bottom ash. Additional influent sources include continuous deionization softeners waste, brine and rinse, and activated carbon filter backwash and brine (Tetra Tech, 2013). The CCR impoundment effluent discharges to the polishing pond immediately east of the Bottom Ash Pond (**Figure 2**). The Bottom Ash Pond ceased receiving CCR and non-CCR wastes in June 2021 when construction of a new treatment system for bottom ash sluice water was completed. The treatment system collects bottom ash solids for beneficial use or disposal and discharges treated effluent to the existing polishing pond.

3.0 Site Hydrogeology/Geology

Prior investigation reports are available documenting hydrogeologic and geotechnical studies completed at the Comanche Station. These include:

- Feasibility Investigation, Two Ash Disposal Areas (Woodward-Clyde Consultants, 1987);
- Geotechnical Investigation, Unit 3 (URS, 2005);
- Coal Ash Disposal Facility Design and Operations Plan (Xcel Energy, 2005);
- Surface Water Impoundment Infiltration Characterization Analysis (GeoTrans, Inc., 2009);
- Inventory and Preliminary Classification Report, Waste Impoundments (Tetra Tech, 2012);
- Sitewide Monitoring Plan, Ash Disposal Facility (Tetra Tech, 2014); and
- Engineering Design and Operations Plan, Ash Disposal Facility (Tetra Tech, 2015 and updated January 19, 2018).

Each of these studies, conducted by different engineering firms over 30 years, investigated the geology, geotechnical characteristics, and hydrogeology of the site and all resulted in a similar hydrogeologic conceptual site model for the Comanche Station as described here.

Comanche Station is underlain by unconsolidated colluvium consisting of stiff clays and silts. Typical colluvium thickness is approximately 20 feet but ranges between 5 and 75 feet (Woodward-Clyde, 1987; URS, 2005). At the southern property boundary and west and south of the CCR landfill, alluvial sand and gravels are interbedded with the colluvium. The colluvium overlies the Pierre Shale bedrock at the Comanche Station. The Pierre Shale is a low-permeability shale that is 1,450 feet thick in this area. The low-permeability shale deposits consist of primarily bentonitic shales, with some interbedded minor chalk and limestone deposits. A water table does not exist regionally in the Pierre Shale (Tetra Tech, 2013). Underlying the 1,450 feet of shale deposits is the Dakota Sandstone Formation (Fm), which is the uppermost aquifer in this region according to literature.

The very low permeability of the Pierre Shale and overriding colluvium has been well documented:

- McKown and Ladd (1982) performed hydraulic-conductivity measurements on three unweathered Pierre Shale core samples. The hydraulic-conductivity values for these samples were reported to range from 4 x 10^{-10} to 8 x 10^{-10} cm/sec.
- Woodward Clyde (1987) installed 10- to 30-foot-deep test holes at Comanche Station for permeability (hydraulic conductivity) testing. These holes were dry and soil samples

were sent to a laboratory for geotechnical testing. Laboratory results showed calculated permeability of 10^{-6} to 10^{-7} cm/sec.

- An investigation of the Pierre Shale at the Pueblo Army Depot (U.S. Geological Survey, 1989) concluded that hydraulic-conductivity values ranged from 3×10^{-10} to 3×10^{-7} cm/sec.
- The 2005 Comanche Station D&O Plan estimated the vertical hydraulic conductivity value for the Pierre Shale to generally range from 10^{-9} to 10^{-6} cm/sec (Tetra Tech, 2017).
- HDR drilled eight wells in August 2020 and submitted samples for laboratory geotechnical testing of permeability by flexible wall permeameter:
  - Colluvium – 3.03×10^{-6} cm/s
  - Weathered shale – 2.72×10^{-8} cm/s
  - Consolidated shale – 6.77×10^{-9} cm/s
- HDR completed well slug tests in October 2020 and analyzed the results to estimate the following hydraulic conductivities (mean values) of subsurface materials:
  - Colluvium – 4.07×10^{-5} cm/s
  - Weathered shale – 2.52×10^{-4} cm/s
  - Consolidated shale (unfractured) – 1.90×10^{-7} cm/s

These low permeability values are consistent with the universally recognized character of shale: aquitard, landfill liner material, used to amend clay to decrease permeabilities for liner materials, sought after formation for underground nuclear waste disposal, and sought after formation as a cap for carbon sequestration.

Any seepage from CCR units to the Dakota Sandstone Aquifer would have to infiltrate through 1,450 feet of the Pierre Shale. Geotrans (2009) estimated groundwater travel time through the shale deposits to take approximately 13,000 years to migrate through the Pierre Shale deposits before water from the CCR units would reach the Dakota Sandstone Aquifer. Tetra Tech (2018) estimated it will take in excess of 14,500 years for groundwater to travel from the site to reach the Dakota Sandstone Aquifer. Therefore, all studies completed at the Comanche site concluded that the shale deposit beneath the site is effectively impermeable.

Studies completed prior to the CCR program development reported that a continuous water table does not exist in the colluvium above the Pierre Shale bedrock (Xcel Energy, 2005; Tetra Tech, 2012; GeoTrans, Inc., 2009). According to GeoTrans (2009), shallow perched water detected in the colluvium deposits beneath the site is not laterally extensive or continuous across the site. When drilling the monitoring network for the CCR groundwater monitoring compliance program in 2015, the uppermost water was targeted. Water was observed in some wells in the colluvial material around the ponds, and drilling ceased when the hollow stem auger hit refusal at the shale consistently across the site. Therefore, the colluvial unit became the uppermost unit to monitor in the early stages of the CCR groundwater monitoring program development (2015-2019), and wells were screened in this unit. Most other wells were found to be dry and therefore a groundwater gradient could not be established. The conceptual site model in the first few years of the CCR groundwater program (2015-2019) was that the shallow unconsolidated colluvium deposits beneath Comanche Station are unsaturated, with an isolated area of perched water in the area of the ponds and a couple pockets of bedrock lows around the landfill, and the impermeable shale was below the colluvium. Because a continuous water table does not exist in the colluvium, there was no measurable horizontal groundwater flow direction or hydraulic gradient. An existing well, W-2 was located topographically upgradient and screened in the colluvium but was consistently dry like all boreholes in the colluvium. Therefore through 2019, insufficient data existed to identify a background well for either CCR unit. This conceptual site model remained consistent with the monitoring observed by HDR between 2015-2019 for CCR monitoring.

In 2020, Xcel initiated an investigation to further characterize the Pierre Shale to support an alternate liner demonstration under the EPA CCR Part B Final Rule (November 12, 2020) (40 CFR 257.71(d)). As that investigation was completed, it was determined core drilling would be utilized to drill and collect undisturbed shale samples. Core drilling allowed for better observations of the shale than had previously been observed from hollow stem auger attempts hitting refusal at the top of shale. The core drilling completed in 2020 made the following observations:

- The uppermost shale beneath the colluvium was found to be fractured between 0 and 20 feet thick. This is now referred to as weathered shale.
- Groundwater was observed in the weathered shale unit.
- Beneath the weathered shale, fractures ceased entirely. Core drilling extended 25 to 41 feet further into the unfractured, consolidated shale in seven borings to confirm the thickness of the consolidated shale.
- Alluvium has been observed above the shale along the southern and southwestern portions of the Station. This was observed in geotechnical borings and in wells MW-4B, MW-6, W-8A/B, and W-9. The alluvium was observed to be dry in all locations except for MW-6.

In response to these observations, Xcel updated the hydrogeologic conceptual site model and in August and December 2020, new monitoring wells were installed around the landfill, around the site perimeter, and to the northeast of the ponds. The updated conceptual site model suggests that the uppermost groundwater beneath the site is in the weathered shale unit; however, in the vicinity of the ponds, there is groundwater observed in the colluvial screened wells. All other wells screened in the colluvium around the site, and geotechnical borings drilled into the colluvium indicate the colluvium is dry. The water in the colluvium around the ponds appears to be mounded shallow perched groundwater of limited aerial extent, as evidenced by the dry colluvial conditions observed during drilling in all directions away from the ponds. Geologic cross-sections are provided in Appendix A. **Figures 3 and 4** display groundwater contour maps in October 2020 and January 2021 and show the groundwater flow direction beneath the impoundment and landfill appears to be generally south in both maps. The October contour map displays the contours for all wells installed as of October 2020 with the exception of dry wells and wells screened in the consolidated shale; this includes contours for wells screened in both colluvium and weathered shale. In contrast to **Figure 3,** which includes water in the colluvium that appears to be mounding in the wells in the vicinity of the impoundment, **Figure 4** (January 2021) provides groundwater contours only for wells screened in the weathered shale and includes the additional wells that were drilled in December 2020. Evaluating the groundwater elevations in wells screened in the weathered shale across the site, a continuous groundwater surface appears to flow south and southeast under the Bottom Ash Pond and landfill, respectively. Now that the groundwater flow direction under the units has been identified, background groundwater has been collected in wells upgradient (north) of each of the CCR units to represents background water quality.

The thickness of the groundwater unit above the consolidated bedrock in wells ranges from less than one foot (0.85 foot) to 24.69 feet.

The groundwater travel time to the Dakota Sandstone aquifer has not changed in the new conceptual site model. With regard to horizontal flow of perched water, the distance from the Bottom Ash Pond to the St. Charles River is approximately 4,000 feet and the nearest potentially downgradient offsite domestic wells are located south and southeast of the Station at approximately 3,300 and 3,950 feet, both screened in alluvium associated with the St. Charles River. Assuming the hydraulic conductivity of the weathered shale as measured in slug tests in 2020 (2.52×10^{-4} cm/s), the potential for lateral migration of groundwater is 50 feet per year. Therefore, it would take on the order of 70 to 140 years for groundwater under the Bottom Ash Pond to travel to the nearest domestic well or 85 to 169 years to reach the St. Charles River.

4.0 Monitoring Wells

The CCR Rule requires, at a minimum, one upgradient and three downgradient monitoring wells per CCR unit to be completed in the uppermost aquifer. The CCR Rule states that downgradient monitoring wells should be installed to: *"accurately represent the quality of groundwater passing the waste boundary of the CCR unit. The downgradient monitoring system must be installed at the waste boundary that ensures detection of groundwater contamination in the uppermost aquifer."*

Based on the CCR requirements, hydrogeological data, and site visits, twenty-seven monitoring wells are monitored; nine at the landfill and six at the impoundment as compliance wells; and seven along the property's eastern boundary, and five along the property's southern boundary to monitor potential effects of the CCR units at a distance **(Figure 2)**.

4.1 Landfill

Tetra Tech (2014) documented four existing monitoring wells (MW-1, MW-2, MW-3, and MW-4) that surround the landfill and are screened in the colluvium just above the colluvium/shale contact. The well locations are shown on **Figure 2**. Given the lack of a laterally extensive shallow groundwater system in the colluvium deposits beneath the site at the time of the well installation, and the great depth to the regional potentiometric surface, a wet/dry monitoring well design was requested by CDPHE and deemed appropriate for the monitoring wells screened in the colluvium (in 2014). Wells MW-1, MW-2, MW-3, and MW-4 incorporate a 2-foot sump consisting of blank casing below the well screen that captures infiltrating perched water that otherwise would be too minimal along the bedrock surface to sample.

Wells MW-5 and MW-6 were installed in August 2017 for CCR compliance to serve as additional monitoring wells for the landfill, including the newly constructed Cell 2E. Wells MW-5 and MW-6 incorporate 10-foot and 5-foot sumps respectively, consisting of blank casing below the well screen (and bedrock surface) that capture infiltrating perched water. The monitored water level in MW-5 is right at the bedrock surface and sampled water is that which accumulates in the sump. MW-6 is screened across alluvium and weathered shale and typically has water in the screened interval.

Colluvial wells MW-1, MW-2, and MW-4 have always been dry. As described in Section 3.0, as the conceptual site model was updated based on new site hydrogeologic characterization borings, three new wells, MW-1B, MW-2B, and MW-4B were installed in August 2020. These new “B” wells were drilled deeper and screened in the weathered shale in order to obtain water samples for the uppermost groundwater surrounding the landfill.

The nine monitoring wells (MW-1 through MW-6 and MW-1B, MW-2B, and MW-4B) that surround the landfill were installed to meet the requirements of the CCR Rule for groundwater monitoring. Since the facility is surrounded by monitoring wells screened above and in the weathered shale, all possible conditions are represented in the collection of uppermost groundwater. The contour maps provided in **Figure 3** and **Figure 4** display the groundwater elevations in October 2020 and January 2021, and shows the groundwater flow direction beneath the landfill appears to be generally southeast in both; and wells MW-3, MW-4B, MW-5, and MW-6 all appear to be generally upgradient of the landfill. Based on the updated groundwater flow conditions under the landfill, only two of the nine monitoring wells appear to be strictly downgradient of the landfill (MW-1B and MW-2B); and therefore Xcel intends to install an additional downgradient monitoring well between MW-2B and MW-1B. Wells MW-3 and MW-5 serve as background monitoring wells for the landfill (**Figure 4**).

Wells MW-6 and MW-4B both encountered sections of alluvium above the shale. The alluvium was dry in MW-4B.

The certified monitoring network for the landfill includes the following wells:

- Background wells: MW-3, MW-5
- Downgradient compliance wells (wells to evaluate impact at and near the CCR unit boundary): MW-1, MW-1B, MW-2, MW-2B,
- Wells installed to be downgradient but have since been determined to be cross gradient: MW-4, MW-4B, MW-6

Wells that are historically dry (MW-1, MW-2, MW-4) will continue to be checked for water levels and if sufficient water is available for sampling these wells will be sampled.

4.2 Impoundment/Bottom Ash Pond

In 1997, monitoring wells W-1, W-2, and W-3 were installed near the CCR impoundment and the nearby settling and polishing ponds to investigate the presence or absence of perched water and the integrity of the 3-foot thick pond liner systems (GeoTrans, Inc. 2009). Well W-1 is located southeast of the polishing pond. W-2 is located northeast of the settling ponds near the eastern boundary of the property and could potentially serve as an upgradient background well; however it is screened in colluvium and has historically been dry (**Figure 2**). Existing wells W-1, W-2, and W-3 serve as CCR Rule compliance monitoring wells.

Wells W-4, W-5, and W-6 were installed in 2015 around the Bottom Ash Pond to serve as additional monitoring wells for CCR compliance. In December 2020, monitoring well W-5B was drilled adjacent to W-5 but deeper and screened in the weathered shale to evaluate any groundwater quality differences between colluvium and weathered shale.

Wells W-2A and W-2B were installed east of the existing well W-2 that has historically been dry (**Figure 2**). Both were drilled deeper than W-2 in order to locate groundwater and obtain water samples for CCR compliance. W-2A is screened in the weathered shale and W-2B is screened in the consolidated shale. Well W-2A monitors groundwater in the weathered shale and is upgradient of the ponds and therefore is the background well for the Bottom Ash Impoundment. Well W-2B is screened in the consolidated shale and therefore the water quality is not appropriate for comparison against the upper groundwater and therefore will not be part of the certified monitoring well network.

The certified monitoring network for the Bottom Ash Impoundment includes the following wells:

- Background wells: W-2, W-2A
- Downgradient compliance wells (wells to evaluate impact at and near the CCR unit boundary): W-1, W-3, W-4, W-5, W-5B, W-6

Wells that are historically dry (W-2) will continue to be checked for water levels and if sufficient water is available for sampling these wells will be sampled.

Well W-5B, located adjacent to W-5 and screened in the weathered shale, appears in early monitoring to have lower concentrations of boron, sulfate, TDS, and detected Appendix IV COIs than the colluvium-screened well W-5. The static groundwater elevation in W-5 is between one and five feet higher than in W-5B. This early data indicates the potential for two groundwater units, separated by a clay zone, as shown in geologic cross sections in Appendix A. Xcel's monitoring network meets the requirements of the CCR Rule, and monitors all potential contaminant pathways; however based on the updated conditions observed under the impoundment in W-5B, Xcel intends to improve the network further to investigate if there is separation between the colluvium and weathered shale. To evaluate this further, Xcel intends to install one or two additional weathered shale monitoring wells located in the vicinity of the impoundment in the downgradient direction (e.g. adjacent to W-6).

4.3 Perimeter Wells

Monitoring wells W-7, W-8A, and W-8B were installed in August 2020, and W-9, W-11, W-12, W-13 were installed in December 2020. All of these wells monitor groundwater conditions away from the CCR units and are therefore considered perimeter wells. W-7 was installed along the property boundary southeast of the polishing pond and east-northeast of the raw water storage supply; W-9 was installed south of W-7 and straight east of the raw water storage supply. W-8A and W-8B were installed along the southeastern property boundary. W-8A was screened in the alluvium and weathered shale, but was found to be dry (**Figure 2**). W-8B was drilled adjacent to W-8A and was screened in the consolidated shale. There is measurable water in W-8B that has accumulated almost two feet in the well since installation in August 2020 and continues to rise a few inches a month but has never stabilized at a static elevation. The well appears to be slowly weeping and therefore is considered functionally dry. In addition, the water quality from the consolidated shale is not appropriate for comparison against the upper groundwater and therefore will not be part of the certified monitoring well network.

Wells W-11, W-12, and W-13 were installed south of the Raw Water Pond and in the direction of the southern property boundary. These wells (W-11 through W-13) are all screened in the weathered shale. Well W-13 was found to be dry. Test hole borings TH-184 and TH-185 were installed in 1987 for a geotechnical study and field located in 2020 just south of W-11, W-12, and W-13, and will be monitored for water levels (**Figure 2**). These two wells are screened in the colluvium and are dry. These wells along the southern edge capture water quality at a greater distance from the CCR units to evaluate potential effects of the units on surrounding areas to the south and southeast.

Wells W-10A and W-10B were drilled to evaluate depth to groundwater as a geotechnical design constraint for new facilities planned for construction in 2021. W-10A is screened in the colluvium and is dry, and well W-10B is screened in weathered bedrock and has groundwater. The location provided valuable additional data for the groundwater potentiometric mapping (Appendix B); however, wells W-10A and W-10B will be monitored for water level only as part of the CCR groundwater compliance monitoring network.

Xcel is conservatively extending their certified groundwater monitoring network to include some perimeter wells in order to evaluate the potential for groundwater moving offsite. Therefore, the following perimeter wells are included in the certified monitoring network:

- Wells to evaluate water quality further downgradient of the Bottom Ash Impoundment compliance wells: W-7, W-8A, W-9, W-11, W-12, and W-13.
- Wells to evaluate water quality further downgradient of the landfill compliance wells: W-11, W-12, and W-13 (these three wells are also compared to the Bottom Ash Impoundment background).
- Test hole borings TH-184 and TH-185 will be monitored for water levels only.

Wells W-8A and W-13 that are historically dry will continue to be checked for water levels and if sufficient water is available for sampling these wells will be sampled.

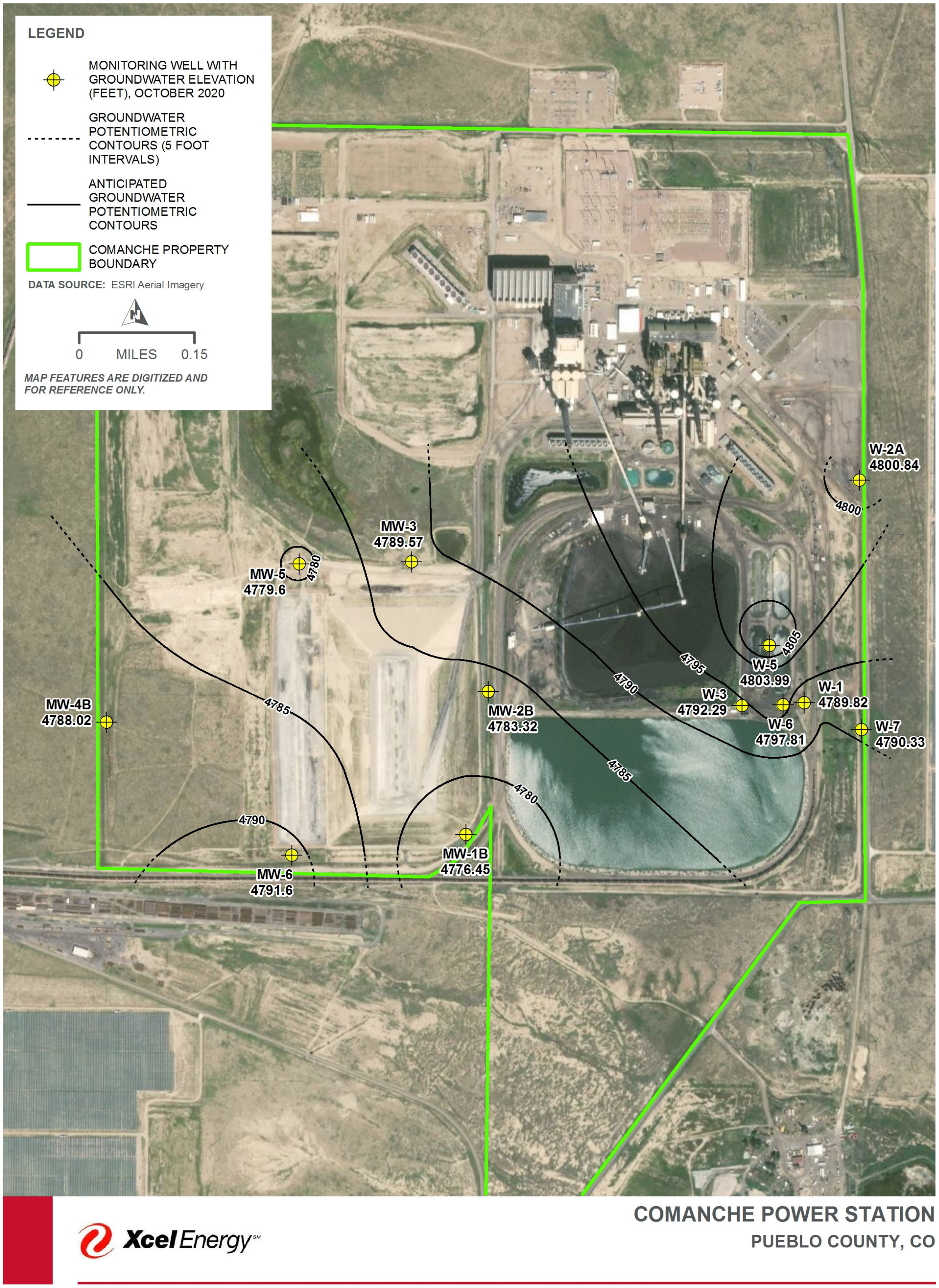

Figure 3. Groundwater contour map showing all wells installed as of October 2020. Wells W-2, W-4, W-8A are not included on the map because they were dry and W-2B and W-8B are not included because they are screened in deeper consolidated shale.

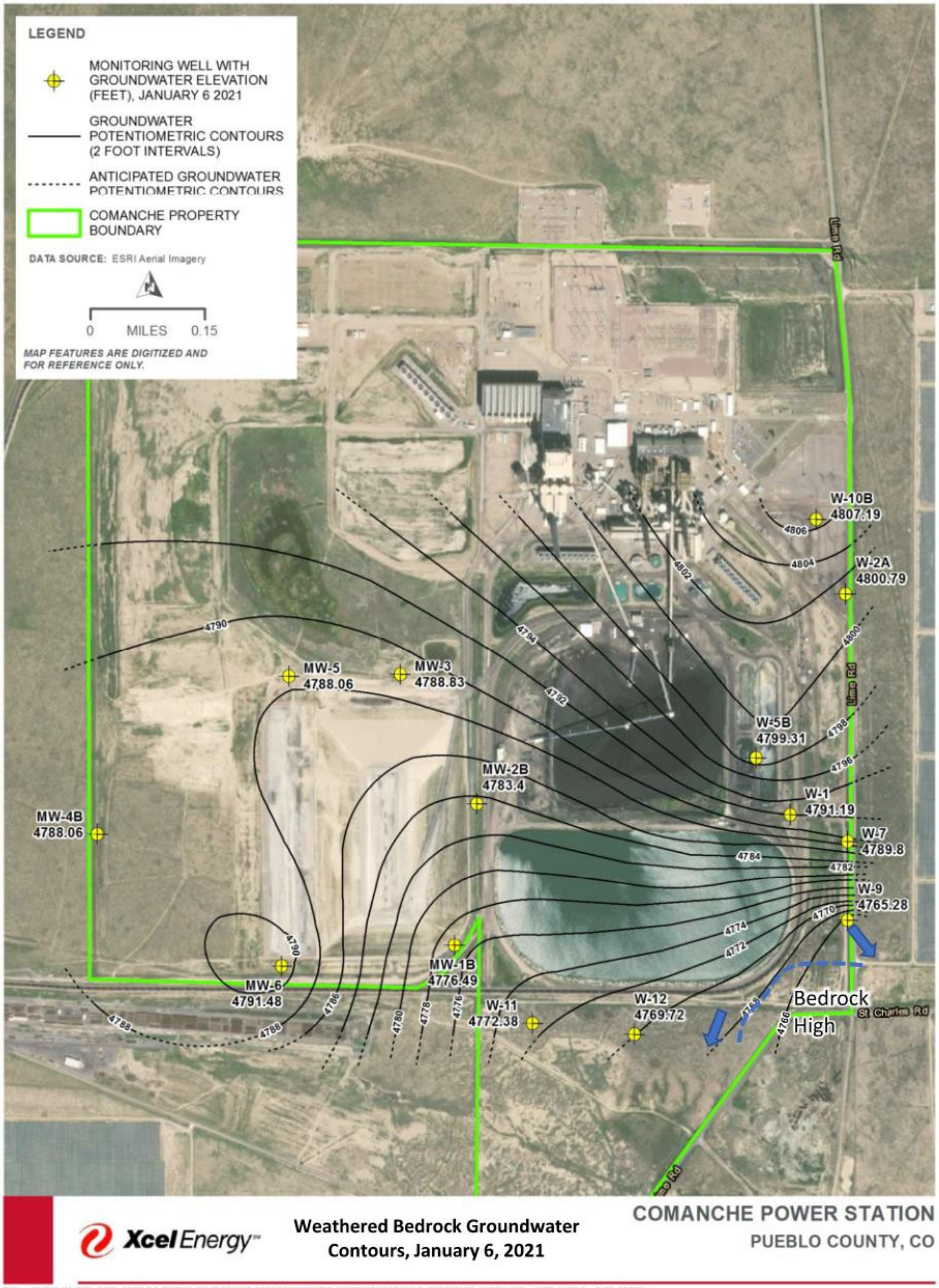

Figure 4. Groundwater contour map of wells screened in the weathered shale.

4.4 Well Construction

The boreholes for monitoring wells were drilled by a licensed well driller. Each well is constructed with 2-inch diameter, Schedule 40 PVC casing and screen with 0.010-inch screen slots. Between 5 and 20 feet of screen was installed in each well. Well construction included 10-20 washed silica sand for the filter pack approximately five feet above the well screen. Annular seals of coated bentonite pellets extend from the top of the filter pack to the surface and were hydrated after placement. Monitoring wells were developed and surveyed. See **Table 2** below for construction details for all monitoring wells.

Table 2. Well Construction Data for Certified Monitoring Well Network

Well I.D.	Northing	Easting	Elevation TOC (ft)	Well Total Depth (ft bgs)	Screen Interval (ft bgs)	Well Stickup (ft)	Well Type	Depth to Water (ft BTOC) Jan. 6 2021	Well Permit Number	Groundwater Elevation (ft asml) Jan. 6 2021	Monitoring Purpose
	(UTM NAD 83 Zone 13, meters)										
MW-1	4228036.700	536722.9491	4806.73	11 (2 ft sump)	4-9	1.89	2-inch PVC	Dry	32282	Dry	Landfill Downgradient
MW-1B	4228051.343	536729.5222	4807.72	40	25-40	2.18	2-inch PVC	31.23	322515	4776.49	Landfill Downgradient
MW-2	4228350.960	536770.7963	4800.45	13 (2 ft sump)	6-11	1.65	2-inch PVC	Dry	32283	Dry	Landfill Downgradient
MW-2B	4228351.208	536776.7356	4801.72	30	20-30	2.39	2-inch PVC	18.32	322514	4783.40	Landfill Downgradient
MW-3	4228624.193	536615.9217	4798.45	11 (2 ft sump)	4-9	1.67	2-inch PVC	9.62	32284	4788.83	Landfill Upgradient
MW-4	4228286.311	535973.3941	4826.47	29 (2 ft sump)	7-27	2.42	2-inch PVC	Dry	32285	Dry	Landfill Downgradient *
MW-4B	4228278.784	535974.9666	4826.41	58	38-58	2.31	2-inch PVC	38.35	322513	4788.06	Landfill Downgradient *
MW-5	4228619.732	536379.9296	4806.97	36.0 (10 ft sump)	16-26	2.43	2-inch PVC	27.19	310106	4779.78	Landfill Upgradient
MW-6	4228008.026	536363.9535	4823.08	42.0 (5 ft sump)	27-37	2.23	2-inch PVC	31.60	310107	4791.53	Landfill Downgradient *
W-1	4228349.085	537432.6122	4799.50	13	3-13	1.87	2-inch PVC	10.18	210284	4789.32	Impoundment Downgradient
W-2	4228796.612	537509.4276	4827.33	17	7-17	1.76	2-inch PVC	15.11	210285	4812.22 (typically dry)	Impoundment Upgradient *
W-2A	4228795.470	537556.6204	4827.86	34	24-34	2.21	2-inch PVC	27.07	322512	4800.68	Impoundment Upgradient
W-3	4228322.278	537309.2055	4807.41	29 (no sump)	14-29	1.04	2-inch PVC	12.11	210286	4795.30	Impoundment Downgradient
W-4	4228491.353	537310.4811	4812.47	23.4 (10 ft sump)	3.4-13.4	3.63	2-inch PVC	26.59	299843	4785.88 (in sump)	Impoundment Downgradient
W-5	4228447.927	537367.3502	4811.89	23.5 (10 ft sump)	3.5-13.5	3.83	2-inch PVC	8.07	299844	4799.39	Impoundment Downgradient
W-5B	4228325	536380	4810.62	36.0	30.5-35.5	2.50	2-inch PVC	11.31	322520	4799.31	Impoundment Downgradient
W-6	4228323.543	537396.3862	4807.46	25 (10 ft sump)	5-15	3.90	2-inch PVC	9.67	299845	4802.22	Impoundment Downgradient
W-7	4228271.427	537560.7976	4797.80	21	6-21	2.33	2-inch PVC	7.74	322519	4790.06	Perimeter / Characterization

Table 2. Well Construction Data for Certified Monitoring Well Network											
Well I.D.	**Northing**	**Easting**	**Elevation TOC (ft)**	**Well Total Depth (ft bgs)**	**Screen Interval (ft bgs)**	**Well Stickup (ft)**	**Well Type**	**Depth to Water (ft BTOC) Jan. 6 2021**	**Well Permit Number**	**Groundwater Elevation (ft asml) Jan. 6 2021**	**Monitoring Purpose**
	(UTM NAD 83 Zone 13, meters)										
W-8A	4227922.799	537487.5324	4804.26	30	15-30	2.16	2-inch PVC	Dry	322518	Dry	Perimeter / Characterization
W-9	4228088	537562	4801.78	40.0	27.35-37.35	2.31	2-inch PVC	36.50	322516	4765.28	Perimeter / Characterization
W-10A	4228951	537490	4835.21	18.0	7-17	2.22	2-inch PVC	Dry	322525	Dry	Water Level Only
W-10B	4228953	539470	4835.22	31.0	20-30	2.21	2-inch PVC	28.03	322524	4807.19	Water Level Only
W-11	4227888	536898	4795.99	34.0	23-33	2.38	2-inch PVC	23.61	322523	4772.38	Perimeter / Characterization
W-12	4227869	537107	4791.65	25.0	14-24	2.22	2-inch PVC	21.93	322522	4769.72	Perimeter / Characterization
W-13	537292	4227853	4801.96	29.0	24-29	2.30	2-inch PVC	Dry	322511	Dry	Perimeter / Characterization

Notes:
* Sited to surround the CCR unit but ultimately appears cross gradient or slightly upgradient of CCR unit.
[+] Well completed in colluvium and is typically dry so data not included in background statistics as of the time of this document.
TOC = top of casing
BTOC = below top of casing
BGS = below ground surface
amsl = above mean sea level

5.0 Groundwater Quality Sampling

5.1 Schedule

Sampling is conducted at a frequency compliant with CCR Part 257.94. Eight rounds of background monitoring were completed before October 17, 2017 for the original Bottom Ash Pond and Landfill wells. Groundwater sampling of those wells was conducted quarterly between the fourth quarter 2015 and the third quarter 2017 for background water quality monitoring. However, as described in Section 3 and 4, the groundwater flow direction could not be established to identify background water quality at that time. Additional wells were installed in 2020 and updated background sampling was performed between August and December 2020. Groundwater detection monitoring was completed in January 2021, and assessment monitoring will continue on a semiannual basis as appropriate based upon the results of analysis in compliance with CCR Part 257.94 and 257.95.

Samples are collected following the protocol in the Xcel Energy Groundwater Sample Collection Standard Operating Procedure (HDR, 2015c). Groundwater quality sampling is conducted in all upgradient and downgradient monitoring wells unless wells are dry. In accordance with the CCR Rule, groundwater samples are not field filtered. The field parameters of turbidity, pH, and temperature are measured using a YSI Professional Plus (or an equivalent) portable water quality instrument that has been calibrated prior to use.

5.2 Analytical testing

Analytical testing of groundwater samples will be performed by TestAmerica or other EPA certified laboratory. For the initial eight background sample events, samples are analyzed for the constituents shown on **Table 3**, which include all of the constituents in Appendices III and IV of Part 257, plus Total Suspended Solids (TSS). For detection monitoring, the constituents listed in Appendix III will be analyzed. Subsequent sampling events will be analyzed for the constituents listed in Appendix III or IV as appropriate, based upon the results of previous sampling and statistical evaluation of results. For quality control, one field duplicate sample and one field equipment blank sample will be collected for each sample event. The laboratory will analyze matrix spike/matrix spike duplicates at a rate of 5 percent, per laboratory quality control standards.

Table 3. Groundwater Quality Constituents
Appendix III Constituents for Detection Monitoring
Boron
Calcium
Chloride
Fluoride
pH
Sulfate
Total Dissolved Solids (TDS)

Table 3. Groundwater Quality Constituents
Appendix IV Constituents for Assessment Monitoring
Antimony
Arsenic
Barium
Beryllium
Cadmium
Chromium
Cobalt
Fluoride
Lead
Lithium
Mercury
Molybdenum
Selenium
Thallium
Radium 226 and 228 combined
Additional Parameters
Total Suspended Solids (TSS)

6.0 Reporting

The CCR Rule 297.90(e) identifies the reporting requirements for the groundwater monitoring program for the CCR units. The annual reporting documents are developed no later than January 31 of each year. The annual reports are placed in the Comanche Station operating record. Annual reports will summarize key monitoring actions completed, describe any problems encountered, discuss actions to resolve the problems, and project key activities for the upcoming year. The data validation, verification, and statistical methods used to analyze each specified constituent in each monitoring well is described in a separate Statistical Methods Certification document.

Xcel will comply with the CCR Rule recordkeeping requirements specified in § 257.105(h), notification requirements specified in § 257.106(h), and internet requirements specified in § 257.107(h).

7.0 References

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